The normal hip joint space: variations in width, shape, and architecture on 223 pelvic radiographs

M Lequesne, J Malghem, E Dion

Objectives: To determine the range of normal radiographic joint space width (JSW) values and the shape of the normal hip, and the influence of age, sex, dysplasia, coxa profunda, and acetabular roof curve abnormalities on these values.

Methods: On routine conventional pelvic radiographs taken in the supine position in patients with no history of hip or lumbar pain, JSW was measured at three points (superolateral, apical, superomedial), together with the VCE, HTE, and neck shaft angles; acetabular depth; and femoral head diameter.

Results: 223 radiographs (446 hips) from 127 women and 96 men (mean age 51.3 years) were examined. Individual variations in JSW were large (apical site: 4.19 (0.92) mm; range 2–7). Mean JSW values were higher at the superolateral site than at the apical and superomedial sites in nearly 80% of cases. Women had lower JSW values than men. JSW values did not fall with age. Marked right/left JSW asymmetry was seen in 179 (5.9%) subjects. Eight cases of acetabular dysplasia (7 unilateral) and 16 cases of coxa profunda were found, but no cases of acetabular protrusion. The JSW was thicker in dysplastic hips, and thinner in hips with coxa profunda. A roof curve abnormality was found in 96/446 (21.5%) hips.

Conclusions: Normal JSW values vary widely; the JSW is commonly narrower at the superolateral site than at the apical site, and is sometimes asymmetric. The roof curve is dysmorphic in about 20% of patients. These findings may have important implications for epidemiological studies and early diagnosis of osteoarthritis of the hip.

More information is needed on the radiographic joint space (JS) of the normal hip, including its shape, its width at precise locations, and the influence of age, sex, and congenital morphology. These normal values are needed to set the limits of significant early radiographic alterations in patients with osteoarthritis (OA). The American College of Rheumatology classifies as "OA" only painful hips meeting at least two of the following three criteria: sedimentation rate <20 mm/1st h, osteophyte, and joint space narrowing (JSN). As epidemiological studies include many painless OA hips, they often include JSN as the most robust and useful radiographic feature. However, in studies of occupational risk, for example, the threshold JS value defining OA of the hip varies among authors from <4 to 1.5 mm, and measurements are generally made only at the apical site. Moreover, owing to a lack of accepted normal values, the JSW of interest is usually compared with the contralateral JSW, which may itself be abnormal.

We found five main published studies offering sufficient methodological details and dealing with the JSW of normal hips. Two comprised 533 x-ray studies on plain urographic and abdominal films, respectively. These radiographic incidences do not encompass exactly the same JS segment as routine radiographs of the pelvis, which are centred at a lower point. The other three studies used pelvic x-ray findings and involved 120, 240, and 171 subjects. All these studies sought differences in JSW according to age and sex. In contrast, we found no studies considering the relationship between JSW and dysplasia, acetabular protrusion, or coxa profunda, or the distortion of the JS shape by possible acetabular roof dysmorphism.

Our study was sponsored by GETROA, a French research group comprising radiologists, rheumatologists, and orthopaedic surgeons, and involved 10 centres in France and one in Belgium (see Acknowledgements). The aims were not only to measure the JSW of normal hips at the three principal sites (fig 1), and to determine the influence of age and sex, but also to check the possible relationship between JSW and primary architectural deformities (dysplasia, acetabular protrusion, and coxa profunda). Furthermore, we examined the shape of the acetabular roof according to the three types noted by one of us over many years (see definitions below).

METHODS

Definitions of the parameters used

For the purposes of this study, the parameters used are defined as follows:

- JSW of the hip on the coronal radiograph refers to the interbone area between the acetabular roof and the part of the femoral head facing it. The roof limits are the lateral extremity of the condensated subchondral bone and, medially, the junction roof-acetabular fossa line (fig 1). The acetabular fossa is devoid of cartilage.
- The VCE angle (Wiberg’s angle) is the angle formed by the vertical line drawn through C (centre of the femoral head) and the line CE, E being the acetabular roof lateral brim (fig 2A). It measures the lateral covering of the femoral head by the acetabular roof; it is considered insufficient (congenital dysplasia) when ≤ 20° and excessive (coxa profunda) when ≥ 40°.
- Clear acetabular protrusion is diagnosed when the acetabular projects medially to the ilio-ischial line by 3 mm or more in men and by 5 mm or more in women.
- The HTE angle is the angle formed by the horizontal line drawn through point T (medial extremity of the acetabular fossa).

Abbreviations: JS, joint space; JSW, joint space width; OA, osteoarthritis.
roof) and the line TE (E: see above) (fig 2A). It measures acetabular roof acclivity and is considered too oblique (dysplastic) when >12°.\(^\text{14 15}\)

- The NSA (neck shaft angle) is formed by the line N (neck axis) and the line S (axis of the femoral diaphysis) (indicated as CC\(^1\)D in fig 2A). It reveals coxa valga when >140°.\(^\text{14 15}\)
- Acetabular depth is defined in fig 2B; this is a criterion of dysplasia (acetabular insufficiency) when ≤9 mm.\(^\text{16}\)
- Acetabular dysmorphias, noted by one of us (ML) over many years, and not hitherto described, were categorised as indicated in fig 3 and were systematically recorded.

Patients

Patients of both sexes aged from 18 to 89 years were eligible for this study if they were free of hip and lumbar pain and required plain radiographs of the pelvis for diagnosis or monitoring of metastasis, bone marrow disease, renal failure, long term steroid treatment, or trauma.

Radiographs

Conventional full size radiographs were taken in the supine position, with the legs in medial rotation of 15°. The focal length was from 1.00 to 1.15 m, according to usual practice in each centre. Only one centre, which provided 14 radiographs, used the 1.15 m focal length. The other centres used the...

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Figure 1 Normal hip joint space. Location of the three sites of JSW measurement. From right to left: the superolateral, the apical, and the superomedial sites (point of arrow).

Figure 2 (A) The VCE, HTE, and NSA (indicated as C\(^1\)D, 140°) angles; (B) acetabular depth: segment ‘ad’ stretches from the deepest point of the acetabulum and the line EP, drawn from the lateral extremity of the acetabular roof to the superior pubic angle.

Figure 3 Sketch of the three main types of acetabular roof dysmorphia: (A) excessively arched roof; (B) excessively flat roof; (C) roof with a prominent segment (angular roof).
1.00 m focal length. We checked that the images of a 4 mm space between two metallic wires, x rayed at focal lengths of 1.00 m and 1.15 m, were impossible to distinguish one from the other. The x ray beam was centred 6 cm above the pubic symphysis.

Exclusion criteria
Patients with known hip disease or pain located in the hip region, including ambiguous pain probably of lumbar origin but irradiating to the region of the greater trochanter, groin, or thigh, were excluded from the study. We also excluded patients with bone disorders such as Paget’s disease, femoral head disease, acquired deformities, unequivocal OA of the hip, and evident osteophytes or cysts adjacent to the hip joint cavity. Films with incorrect patient positioning (misalignment of the sacrum-pubic symphysis vertical axis >1.5 cm) were also excluded.

Measurements
All measurements were made using a new Plexiglass instrument, the “arthrometer”, designed by one of us. It comprises a ruler for JSW measurement and protractors of the above-mentioned angles and segments twice, 1 month apart, to evaluate intraobserver and interobserver reproducibility of two readers “blindly” measuring JSW and all the above-mentioned angles and segments twice, 1 month apart, on the same series of 30 x ray pictures. The reader with the best intraobserver reproducibility made all subsequent measurements.

Statistical analysis
Reproducibility was expressed as the standard measurement error, intraobserver reproducibility, and limits of agreement.17 The Shapiro-Wilk test was used to determine the normal or non-parametric distribution of variables. The variables, all of which were quantitative, were analysed by analysis of variance bilateral Student test; the Wilcoxon rank test was used for non-parametric variables; p values of <0.05 were considered significant. The significance of correlations between parametric variables was expressed by Pearson’s correlation coefficient. Spearman’s correlation coefficient was used for non-parametric variables. All analyses were performed using SAS software version 6.12.

RESULTS
Population
A total of 265 patients were eligible for the study. Thirty seven pelvic radiographs were excluded because of positioning or centring errors. Among the remaining 228 films (456 hips), we eliminated 10 hips (3 bilateral and 4 unilateral) with an unequivocal aspect of OA, osteophytes, and/or cyst(s). The remaining 446 assessable hips belonged to 127 women and 96 men with a mean age of 51.3 years (SD 16.0; range 16–88). The reasons for pelvic radiography were metastas screening in 44 cases; bone marrow disease in 12; renal failure in 64; long term steroid treatment in 36; trauma in 38; and miscellaneous in 31. Two patients had two reasons for pelvic radiography.

Reproducibility
Table 1 shows the intraobserver reproducibility of the two readers. Interobserver reproducibility, expressed as the intraclass correlation coefficient with regard to JSW (apex), VCE, HTE, NSA angles, and acetabular depth, was 0.78, 0.90, 0.89, and 0.95, respectively. Femoral head diameter measurement was very reproducible, with a coefficient of variation of 1.6% and an intraclass correlation coefficient of 0.99.

JSW values and correlations
The mean JSW at the apical site was 4.19 mm (SD 0.92, range 2–7).

Mean JSW values were higher at the superolateral site (4.82 mm) than at the apical site (4.19 mm), and higher at the apical site than at the superomedial site (3.61 mm). The differences were significant (p = 0.02 to 0.0001 according to the location) in both men and women. Women had a significantly smaller JSW than men (p = 0.02 to <0.0001 according to the location) (table 2).

In 378 hips, mean JSW was higher at the superolateral site than at the apical site and higher at the apical site than at the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Intraobserver reproducibility of measurement of the main variables</th>
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<tr>
<td></td>
<td>Standard error of measurement (95% CI)</td>
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<td></td>
<td>1st Observer</td>
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<tr>
<td>JSW (mm)</td>
<td>0.26 (0.20 to 0.38)</td>
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<tr>
<td>VCE angle</td>
<td>1.04 (0.79 to 1.52)</td>
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<td>HTE angle</td>
<td>0.78 (0.56 to 1.21)</td>
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<tr>
<td>NSA angle</td>
<td>1.35 (1.02 to 1.97)</td>
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<tr>
<td>Acetabular depth (mm)</td>
<td>0.35 (0.27 to 0.52)</td>
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<tr>
<th>Table 2</th>
<th>Joint space width (JSW) in three locations in 446 normal hips. Mean (SD) [range], in mm</th>
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<tr>
<td></td>
<td>Superolateral</td>
</tr>
<tr>
<td>Women &amp;n = 127</td>
<td>4.69 (0.95)</td>
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<td>[3–8]</td>
<td>[2–6]</td>
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<tr>
<td>Men &amp;n = 96</td>
<td>5 (1.15)</td>
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<tr>
<td>[3–8]</td>
<td>[2–7]</td>
</tr>
<tr>
<td>Both sexes &amp;n = 223</td>
<td>4.82 (1.05)</td>
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<tr>
<td>[3–8]</td>
<td>[2–7]</td>
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<th>Table 3</th>
<th>JSW according to age (before/after 50 years)</th>
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<td></td>
<td>16–50 years (n = 220)</td>
</tr>
<tr>
<td>Superolateral</td>
<td>4.77 (1.02)</td>
</tr>
<tr>
<td>Apical</td>
<td>4.09 (0.92)</td>
</tr>
<tr>
<td>Superomedial</td>
<td>3.60 (0.93)</td>
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</table>
superomedial site. Among the remaining 68 hips (15.2%), mean JSW was identical at the three sites in 40 cases (9%), while 28 hips (6.3%) showed lower JSW values at the superolateral site than at the apical site (18 hips), the superomedial site (9 hips), or both latter sites (1 hip).

JSW asymmetry exceeding 1.45 mm—that is, the limits of agreement—at one or more of the three sites was found in 13221 (5.9%) patients; side to side comparison was not possible in two cases. The number of cases of asymmetric JSW at the superolateral site only, the superomedial only, both the superolateral and apical sites, and on the whole JS were 5, 3, 3, and 2, respectively.

Interestingly, JSW did not diminish with age: on the contrary, it was higher after 50 years than before 50 years. However, the difference was not significant when only subjects aged 25–50 years were compared with those aged 50–88 years (table 3).

Table 4 shows values of VCE, HTE, NSA angles, and acetabular depth. Acetabular dysplasia, considered as a VCE angle <20°, was found in nine subjects and was unilateral in all nine cases (4%). Acetabular dysplasia, defined as a VCE angle ≤20° with acetabular depth <9 mm, was found in eight subjects (3.6%) and was unilateral in seven cases. These two groups of dysplasia, which have only slightly different definitions, almost entirely overlap with each other.

The VCE angle was inversely proportional to JSW at the superolateral and superomedial sites (Pearson’s p = 0.27 and −0.35, respectively), whereas the HTE angle was proportional to JSW at the same sites (Pearson’s p = 0.32 and 0.37, respectively) (table 5). Likewise, when we compared apical and superomedial JSW values between patients representing the 10th and 90th centiles of VCE values, the largest JSW values were associated with the smallest VCE angles, and the lowest JSW values were associated with the largest VCE angles. Similar results were obtained when the smallest and lowest JSW values correlated with the largest VCE angles. In that study, as in most others, men had a larger JSW than women (3.78 (0.67) mm vs 3.43 (0.4) mm)—that is, a mean difference of 0.35 mm). Using the JSW narrowest point on intravenous urography films, a recent English study showed a similar JSW difference between men (n = 257) and women (n = 276): 0.34 mm (95% CI 0.24 to 0.44). However, the site of measurement was the JSW “narrowest point”, and supine abdominal radiographs rather than pelvic radiographs were used.

In that study, as in most others, men had a larger JSW than women (3.78 (0.67) mm vs 3.43 (0.4) mm)—that is, a mean difference of 0.35 mm). Using the JSW narrowest point on intravenous urography films, a recent English study showed a similar JSW difference between men (n = 257) and women (n = 276): 0.34 mm (95% CI 0.24 to 0.44). We confirm that the JSW is larger in men than in women.

The JSW does not become narrower with age, except, according to Lanyon et al., in women. In our series, values tended to be lower at the superolateral site in young adults (16–50 years) than in the 51–88 year age group (4.77 (1.02) mm vs 4.89 (1.06) mm) (table 3). However, this difference was attenuated when 16–24 year olds were excluded from the “young adult” group (table 3, last column). It is noteworthy that an anatomical study of femoral head cartilage thickness showed that hyaline cartilage does not reach its maximal thickness before age 25 years.

The minimal normal hip JSW value is important for epidemiological studies of OA, where a diagnostic cut off point of 2.5 mm is generally used; this seems appropriate when the JSW is measured at the superolateral site, but the
site of measurement is not always mentioned. In our series, the minimal JSW values were 3 mm, 2 mm, and 2 mm at the superolateral, apical, and superomedial sites, respectively (table 2). In our study, all hips with JSW <2 mm were associated with osteophytes and/or cysts, and were therefore excluded from the analysis of normal values. To define a threshold beneath which the JSW may be considered pathological, one can either choose the minimal value at the appropriate site or adopt the lower normal values, defined as mean – 2SD, that is 2.72, 2.35, and 1.81 mm, respectively, at the three sites. These values were close to the generally used cut off point, except for JSW at the superomedial site, which is rarely considered by itself for setting a limit between normal and pathological JSW. Few data have been published on this point, and our results showing a relatively thin superomedial JSW in normal hips are therefore difficult to compare with previous studies. It seems reasonable to use minimal JSW values of 3 mm, 2 mm, and 2 mm for the three sites considered (table 2).

A JSW gradient, with a decline from the superolateral site to the superomedial site (fig 1), was found in about 80% of hips in our series. To our knowledge, this JSW gradient has only been mentioned in two previous reports. Reis et al measured the JSW at all three sites on pelvic radiographs of 171 healthy subjects, using a magnifying glass with 0.1 mm graduations, and found higher values at the superolateral site than at the apical (“superointermediate”) site, and higher values at the apical site than at the superomedial site (table 7),* with a distribution similar to that found here (table 2). In another study of supine pelvic radiographs of 25 healthy men aged 45–65 years, a significant difference was found in 15.2% of our patients, and lower values at the superolateral site than at the apical or superomedial site in 6.2% of patients. This implies that a lower JSW value in the target hip than on the contralateral side is not sufficient to establish a diagnosis of OA when the measurement is only made at the superolateral site.

Asymmetry in normal subjects is relatively rare: taking into account only right/left differences above the limit of agreement (that is, 1.45 mm), we found 13 subjects with clear asymmetry of 1.5–2 mm. Likewise, Reis et al, in a ruler based study, found asymmetry of 0.6 mm or more in only 5% of cases. As in our series, Reis et al found that JSW asymmetry was most common at the superolateral site.

The prevalence of acetabular dysplasia is interesting to consider. However, it may have been underestimated in our population (mean age 51.3 years), as OA—which was excluded from our study by definition—is often present before age 50 years in cases of dysplasia. In the present study, acetabular dysplasia was present in eight or nine subjects, depending on the definition, and it was bilateral in only one subject (see “Results”). In contrast, coxa valga, that is an NSA angle >140°, was bilateral in most of the subjects. Its borderline value (140°) was reached in five instances (bilaterally in two) and was between 141° and 144° in eight subjects (bilaterally in seven). We found no cases of acetabular protrusion as defined by Armbuster et al.13 Coxa profunda, defined as an excess of covering (VCE = 45°), was found in 16 subjects (table 6).

We found no studies examining the relationship between JSW values and the congenital acetabular architecture. This architecture is characterised by the VCE or Wiberg angle and

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**Table 7** JSW in three sites in 171 normal subjects (342 hips) mean (SD) [range]. Reproduced from Reis et al,* with permission

<table>
<thead>
<tr>
<th>No</th>
<th>Superolateral</th>
<th>Apical</th>
<th>Superomedial</th>
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<tbody>
<tr>
<td>Women</td>
<td>98</td>
<td>4.57 (0.69) [2.6–6.5]</td>
<td>4.21 (0.68) [3.0–7.5]</td>
</tr>
<tr>
<td>Men</td>
<td>73</td>
<td>4.96 (0.81) [2.8–7]</td>
<td>4.49 (0.83) [2.2–7.4]</td>
</tr>
<tr>
<td>Total</td>
<td>171</td>
<td>4.74 (0.81) [2.6–7]</td>
<td>4.33 (0.76) [2.2–7.5]</td>
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*Reproduced from Reis et al.

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**Figure 4** Cybernetics of the growing cartilage regulating (negative) feedback. The system input is the pressure (in the standing position) exerted on cellular receptors (chondrocytes of the deep layer). These cells build the matrix, which is the outcome. The thicker the matrix (acting as a “cushion”), the lower the pressure exerted on deep chondrocytes. At a certain point, matrix secretion stops through a lack of stimulation. Thus, the higher the pressure (cm² in hip dysplasia), the thicker the matrix.
by the HTE angle (roof obliquity vis a vis the horizontal axis)\textsuperscript{14,15} (fig 2). We found a moderate but significant relationship between JSW and the VCE angle (negative correlation), and between JSW and the HTE angle (positive correlation) (table 5). In contrast, we found no relationship between JSW and either acetabular depth or the NSA angle. Mean JSW was significantly larger in hips with acetabular insufficiency and smaller in hips with coxa profunda (tables 5 and 6). We have previously postulated that these features may be explained by a self regulated increase in articular cartilage thickness during growth (fig 4)\textsuperscript{22}; pressure on the hip cartilage would be higher in acetabular insufficiency, leading to thicker growth, while the contrary would apply in coxa profunda. Consequently, in patients with unilateral dysplasia, the hip with a normal acetabular roof would have a thinner JSW than the dysplastic hip, and this would not necessarily imply a joint space narrowing reflecting OA. Conversely, in a hip with unilateral acetabular insufficiency, OA should be considered if the JSW is the same on both sides: the possibility that the dysplastic hip might have lost a certain proportion of its normal excessive JSW should be considered. In doubtful cases, the false profile of the hip may help to diagnose early OA.\textsuperscript{23}

A similar relationship between mechanical solicitations (dynamic and static forces) and a given anatomical configuration during development and the thickness of a cartilage or a disc is found in another study. The height of the lumbar disc is dependent on the configuration of the L5-S1 junction: the less mobile the L5 vertebral body (deeply situated between, and closely attached to, the medial iliac walls), the thinner the L5-S1 disc: $r = 0.618$ ($p<0.0001$).\textsuperscript{24} A cybernetic hypothesis may be applied to this disc location, likewise: the authors suggest that the L5-S1 disc height can be evaluated and interpreted in connection with this anatomical variable—that is, the situation (level) of the L5 vertebral body, as we indicated above for the acetabular anatomy.

Various types of acetabular roof curve abnormalities (roof dysmorphias) (fig 5) were found in 21.5% of hips in our series, with no correlation with sex, the affected side, or dysplasia. These roof dysmorphias obviously alter the shape of the joint space. This finding does not imply OA in the absence of other criteria such as osteophytes or cysts. We found no published studies of such roof shape abnormalities, and no information about whether or not they represent a risk factor for OA of the hip.

This study has several limitations. The relationship of JSW with height and weight has been established in previous studies. We did not re-examine this point, as weight and even height were altered in a considerable proportion of our patients, as a result of the disease for which radiological studies were indicated. We did not record past sporting activity, the dominant side, or possible occupational overwork during adolescence, which are possible causes of JSW augmentation. The correlation of the JSW between the right and left hip was not considered; however, clear asymmetry was recorded (5.9%) and was similar to that found in another study.\textsuperscript{3} The statistical method we chose considered all individual hips as independent, which is debatable. This choice was made prospectively, in order to avoid missing certain rare but important unilateral abnormalities. Indeed, we observed seven unilateral dysplastic hips (3.1% in our series). If only one hip for each pelvis x ray examination had been randomly selected, the prevalence would have fallen to 1.5%, and the risk of missing such an event in a series of 223 subjects would have been 10–15%.

In conclusion, JSW values of 446 normal hips varied widely, from 3 to 8 mm and from 2 to 6 mm at the superolateral and superomedial sites, respectively. In general, JSW decreases from the superolateral site to the superomedial site. However, no such JSW gradient is found in 21% of hips, implying that this feature alone is unreliable for the diagnosis of OA. In the same way, a small proportion of healthy subjects (5.9% in this series) show clear right/left JSW asymmetry.

Finally, the JSW should be assessed according to the acetabular configuration, being larger in dysplasia and smaller in coxa profunda, independently of OA. Likewise, roof curve abnormalities (excessive or inadequate curvature, or angularity) may create pseudo-JS narrowing, for obvious geometrical reasons.

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